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(54) Electrophotographic Color Printing Method and Apparatus

(57) An elongate substrate such as a strip of paper, fabric, synthetic resin sheeting, or foil is imprinted with a plurality of images of different colors successively and in registration to achieve a composite multicolored image.

The apparatus includes a plurality of independent image printing stations through which the substrate is passed.

In one embodiment each image printing station includes one electrophotograhic sleeve. A latent image corresponding to one of the color images of the composite image is formed on the sleeve. The image so formed is toned, transferred to the substrate and then fixed thereto. In another embodiment each image printing station includes two electrophotographic sleeves. A latent image corresponding to one of the color images of the composite image is formed on one of the two sleeves. The image so formed is toned and then optically projected onto the second sleeve. The projected image on the second sleeve is toned, transferred to the substrate and then fixed thereto.

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The specification as originally filed contained illegible matter.

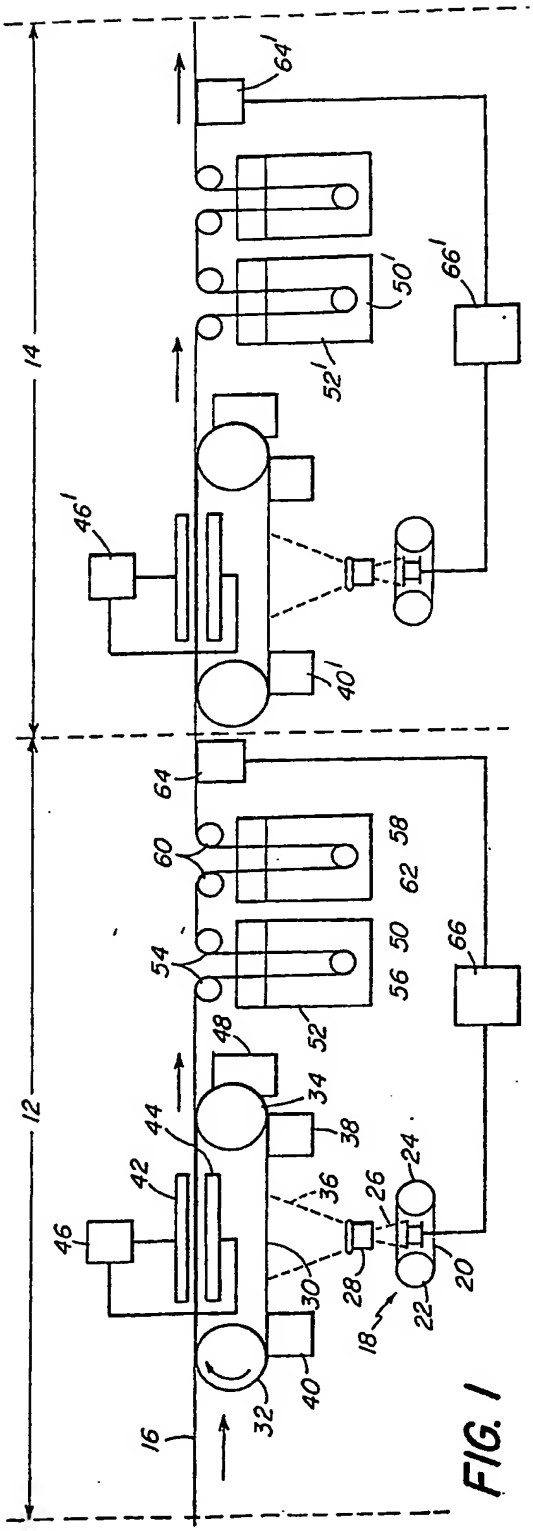

FIG. 1

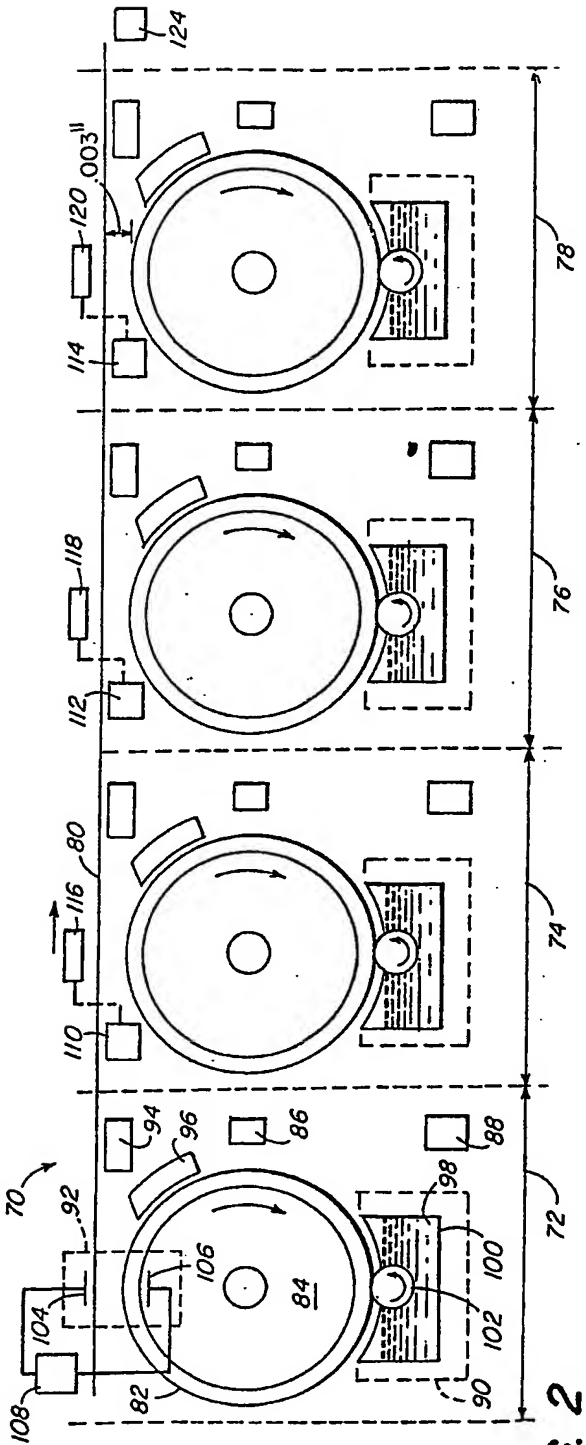

FIG. 2

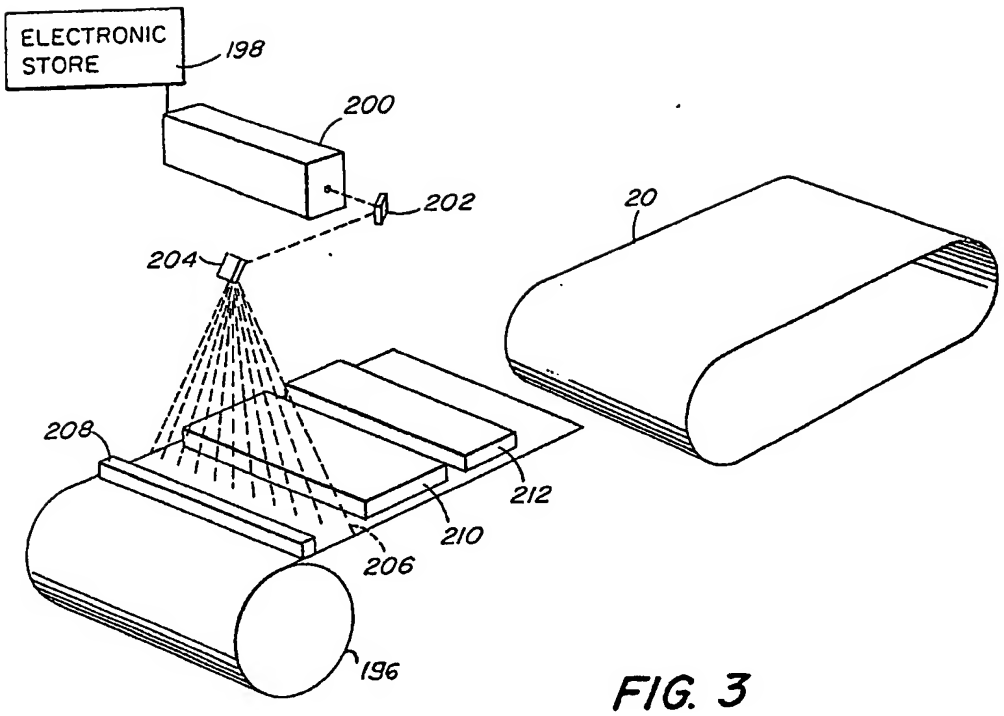

FIG. 3

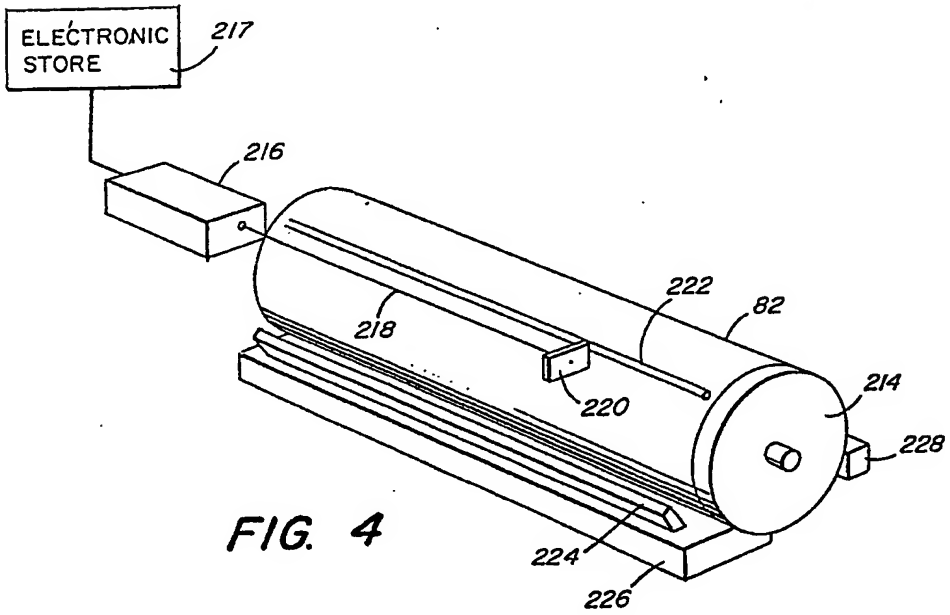

FIG. 4

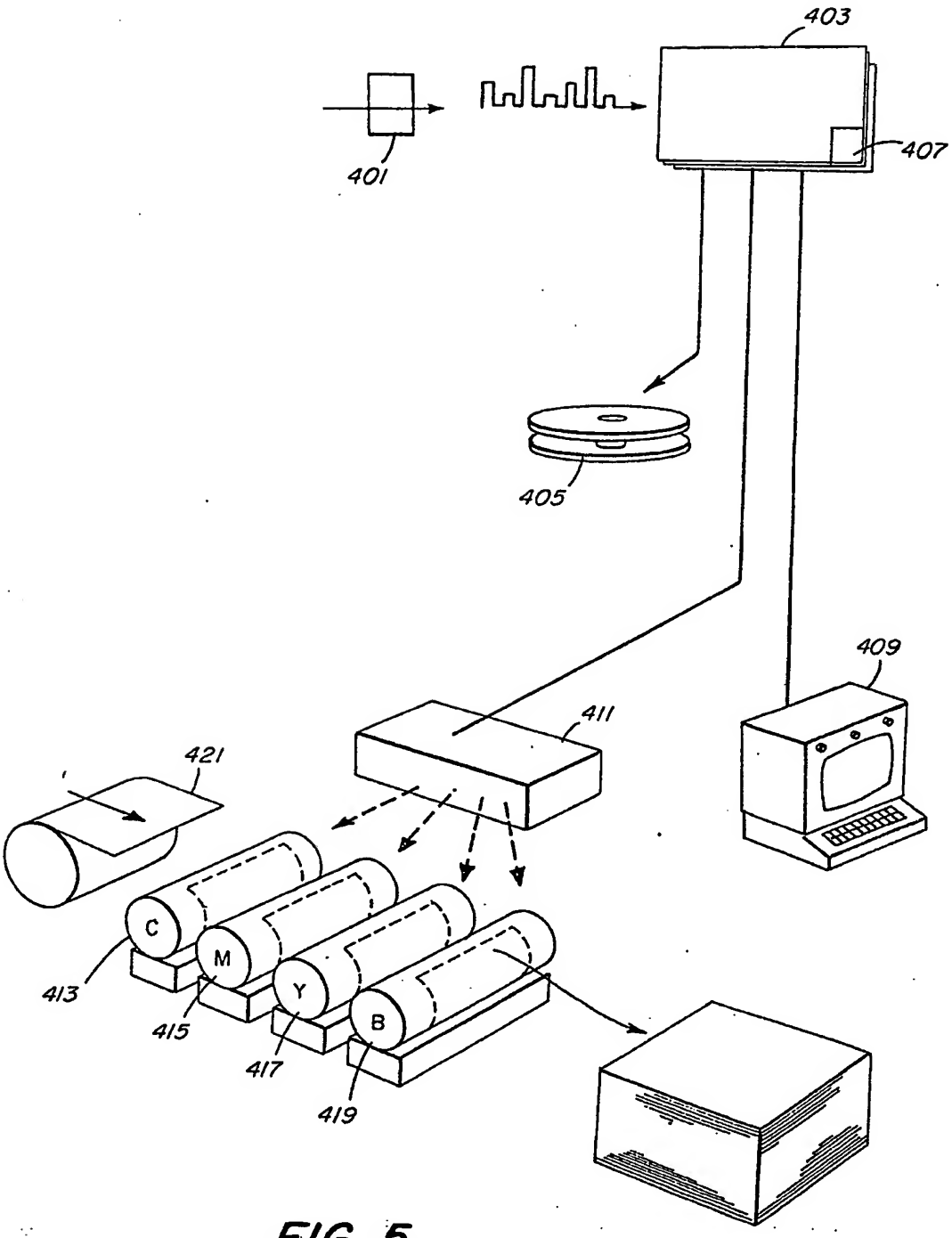

FIG. 5

SPECIFICATION

Electrophotographic Colour Printing Method and Apparatus

Background and Field of the Invention

The field of the invention comprises color printing apparatus and more particularly is concemed with color printing apparatus which operates on electrostatic principles rather than upon the conventional principles used in graphic art printing or photography.

Systems for multicolor printing employing electrostatic techniques are known but for the most part these systems have proven to be complex, expensive unreliable and not capable of producing images of the quality that is desired.

Summary of the Invention

An electrophotographic color printing method and apparatus in which an elongate substrate such as a strip of paper, fabric, synthetic resin sheeting, foil or the like is imprinted with a plurality of images of different colors to achieve a composite multicolored image.

The apparatus includes a plurality of independent image printing stations through which the substrate is passed.

In one embodiment of the invention each image printing station includes one electrophotographic sleeve. A latent image corresponding to one of the color images of the composite image is formed on the sleeve. The image so formed is toned, transferred to the substrate and then fixed thereto. In another embodiment of the invention each image printing station includes two electrophotographic sleeves. A latent image corresponding to one of the color images of the composite image is formed on one of the two sleeves. The image so formed is toned and then optically projected onto the second sleeve. The projected image on the second sleeve is toned, transferred to the substrate and then fixed thereto.

In both embodiments means are provided for achieving exact registration of the images transferred to the substrate from each station.

The single color image formed at each station may be formed by projection from a color picture, color transparency or the like using different color filters etc. or may be formed by "laser writing".

The image may be formed (and toned) on the sleeve before the sleeve is mounted in the image printing station or after the sleeve is mounted in the image printing station.

The image printing stations are preferably arranged in alignment and are independently operative so that different conditions for optimum transfer can be obtained at each station. The image applied from each station is fixed on the substrate before the substrate has moved that image to its following station. The toner, voltages, temperatures and the like at any one station may be different from those same conditions at all others. This arrangement of independent stations along a line provides flexibility in achieving best results.

The electrophotographic sleeves are comprised of a photoconductive coating on a conductive substrate.

In the embodiment where the toned image is transferred from a first sleeve to a second sleeve and then to the substrate, the first sleeve is transparent so that a suitable source of radiant energy can be directed through this sleeve onto a second sleeve. This second sleeve is charged before receiving the projected image from the first sleeve, is toned after receiving the projected image, and then brought into direct engagement or close engagement with the passing substrate, the whole of the toned image being thus transferred. Thereafter the process is repeated for the different colors at respective stations. These images are fixed between stations.

Measurements of density can be made at any station and the information fed back to previous stations to change the parameters of the printing conditions thereat.

The embodiment of the apparatus employing two sleeves at each station is particularly useful in making multiple or repeated prints of a color pattern on an elongate substrate since the toned image formed on the first sleeve remains on the first sleeve. The embodiment of the apparatus employing a single sleeve at each station is particularly useful in making a single color print of a picture or object. Either version, however, can be used for all applications and either version can be used where the input information to be printed is digitized information from a computer.

In the embodiment of the apparatus employing a single sleeve at each station the toned image must be toned to the desired color and obviously must not be fixed to the sleeve. In the embodiment of the apparatus employing two sleeves at each station, the toned formed at the first sleeve need not be the desired color to be printed and can if desired, be fixed to the first sleeve.

In forming the latent images on the electrophotographic sleeves by "laser writing" digitized information from a store corresponding to the desired multicolor print is used to modulate a laser beam that sweeps the surface of each sleeve which has been precharged.

Both embodiments can be used to make repeated color patterns on an elongate substrate or one or more color prints on an elongate substrate.

Brief Description of the Drawings

Figure 1 is a diagrammatic view of one form of an apparatus embodying the invention;

Figure 2 is a diagrammatic view of another form of an apparatus embodying the invention;

Figure 3 is a diagrammatic view showing a method of making a electrophotographic sleeve for use with the invention;

Figure 4 is another diagrammatic view showing a second method of making an

electrophotographic sleeve for use with the invention; and

Figure 5 is a diagrammatic representation of an entire system for making color prints employing the method and apparatus of this invention.

Description of Preferred Embodiments

The printing method of the invention involves the making of a different toned image electrophotographically on each one of a plurality of electrophotographic sleeves; the toned image on each sleeve corresponding to one of the color images in the composite color print. The sleeve rotates about its own axis and either contacts the substrate directly in which case it rotates in the same direction as the substrate or serves as a projection medium through which the toned image so formed is projected onto a second electrophotographic sleeve where it is toned, this latter toned image then being transferred directly to the moving substrate from the second sleeve.

One of the important aspects of the invention is that the apparatus includes a plurality of image printing stations each of which is independently controlled as to the various parameters required to produce the necessary impression or image on the substrate.

In Figure 1 there is illustrated an apparatus designated generally by the reference character 10 for making a color print by the indirect transfer method. The apparatus includes a plurality of stations, two of which are shown at 12 and 14. Each of these stations is intended to apply an imprint of a different color to a substrate 16 which is shown entering the station 12 on the left and leaving the station 12 to enter the station 14 on the right. For multi-color printing it is usual to have at least three and more often four colors, these being cyan, magenta, yellow and black so that it would be expected that the usual apparatus of the invention will have four such stations. In the case of fabrics, the number of stations would usually be expected to comprise the number of colors and shades carried by the fabric since generally composite colors are not achieved through mixture.

At the station 12 there is shown an image projecting apparatus 18 which comprises a master sleeve 20 that in this case is in the form of an electrophotographic belt carried on rollers 22 and 24 and having an optical illuminated projector 26 disposed below the upper reach of the master sleeve or belt 20 and adapted to project any image carried on the belt through a projection lens or system 28.

The belt 20 will carry an image preferably in the form of a digital coded color separation which has been applied to the belt in a manner to be described especially in connection with Figures 3 and 4. At this point it may be said that the belt is formed of an electrophotographic material or member comprising a substrate of a transparent polyester which carries an ohmic layer and a coating of photoconductive material on the outside thereof. The photoconductive material comprises an inorganic compound, preferably cadmium sulfide, which has been sputtered onto the substrate as a microcrystalline, transparent, high quantum yield deposit of the type which is disclosed in U.S. Patent 4,025,339. The method of coating the substrate is also disclosed in that patent.

At the station 12 there is a second sleeve 30 which extends and rotates between the rollers 32 and 34. Its lower reach is exposed to the image 36 which is projected by the lens system 28 and its upper reach is in engagement with the under side of the substrate 16. The speed of the substrate in moving from left to right and the speed of the sleeve 30 are chosen such that the movement is synchronized. The rollers 32 and 34 may be driven to achieve this movement, the sleeve being in the form of a belt. The material of the second sleeve 30 is the same as the material of the master sleeve 20; hence, it is an electrophotographic member, the photoconductive coating being on the exterior of the sleeve.

Throughout this specification it is presumed that there will be drive means for moving sleeves, rollers, substrate and cylinders as needed and under suitable control.

An electrostatic corona device is disposed at 38 for the purpose of charging the lower surface of the second sleeve 30 just before it enters the area of the beam 36. It is appreciated that the lower reach of the second sleeve moves from right to left. At 40 is a toning device which would contain preferably a type of toner that is compatible with the type of substrate 16. For example, if the substrate 16 is paper the toner used with the toner apparatus 40 will be suitable for transfer to paper. It may or may not be dielectric. Its color and composition will be determined by the requirements of printing.

The now developed image moves around the roller 32 and meets the bottom of the substrate 16 as it moves through the station 12. Bias plates are shown at 42 above the substrate 16 and 44 below with the combined upper reach of the sleeve 30 and the substrate 16 passing between. These plates 42 and 44 are connected to a power supply 46 by means of which an electric field is established between the plates for the purpose of biasing the toner particles to be driven from the upper reach of the sleeve 30 to the bottom surface of the substrate 16. While transfer of the toned image may be effected mechanically by pressure, it is preferred that there be a slight space between the upper reach of the sleeve 30 and the substrate 16 so that there is no wear on the surface of the sleeve 30 and no likelihood of smearing.

After the imprint has been made, and it is assumed that it will be in or for the purpose of achieving a single color, the belt moves around the roller 34 and passes a cleaning station at 48 which removes any of the toner which may have remained on the sleeve 30 so that when that area

of the second sleeve 30 passes to the charging apparatus 38 again it will be clean.

Assuming that the substrate 16 is fabric and that the toner which has been furnished by the toner apparatus 40 is an electrostatic mordant, after the imprint has been made the substrate 16 is passed into a tank 50 where the dye to be absorbed by the mordant is carried as shown at 52. The substrate 16 passes over the rollers 54 and 56 in passing through the dye tank 50.

It will be appreciated that in the case of fabric the toner mordant will normally have no pigment, but will merely comprise the type of chemical that adheres or is absorbed by the fabric fibers which are to take on the dye 52. In the case of a paper or other substrate, the toner will be pigmented and there will be no dye tanks but instead the substrate 16 will be led past a fixing element or elements as will be explained and to the next station.

Continuing with the description of the station 12, after the substrate has been dyed, it is passed into a rinsing tank 58 over the rollers 60 and 62 at which all of the mordant is rinsed out. There may be a drying apparatus at station 12 after the rinsing tank but this is not shown.

At 64 there is illustrated a block which represents an optical transducer that responds to the density of the impression which has been achieved in the station 12. This transducer provides a signal related to the density that is converted at 66 into a control signal for varying the intensity of the illuminating source in the projector 26. In this way it is possible to control the pattern intensity produced at the station 12.

Station 14 is identical in all respects to station 12; hence, there is no need to describe it in detail. The difference will lie in the color of the dye 52′ in the dye tank 50′. The parameters of bias furnished by the power supply 46′, the type of mordant in the toning apparatus 40′ and the characteristics of the signals at 64′ and 66′ may differ because of the different color which is involved.

In Figure 2 there is shown a second form of printing apparatus 70 which for illustrative purposes has four stations 72, 74, 76 and 78.

The substrate 80 passes straight through without being diverted as is the case with the apparatus 10. At the first station there is a master sleeve 82 which is mounted on a roller 84. The master sleeve 82 is an electrophotographic member but is cylindrical instead of oval shaped as in Figure 1. The construction of the sleeve may be similar to that of the sleeve 20 except that there is no need for transparency in this case. Preferably the sleeve 82 comprises a coating of the same type of photoconductive material described above applied to a thin, metal cylinder that is maintained in its cylindrical condition upon the roller 84 by suitable means.

Image printing station 72 includes an electrostatic charging substation 86, an imaging substation 88, a toning substation 90, an image transfer substation 92, an image fusing substation 94 and a toner cleaning substation 96.

In use, sleeve 82 is passed through the charging substation 86, which may be in the form of a corona generator, where it is uniformly electrostatically charged. The sleeve 82 is next passed through the imaging substation 88 where a latent electrostatic image is formed thereon by projection, or by laser writing or other suitable means. Registration marks (not shown) are also put on the sleeve at a specific location next to the image at this substation. The registration marks may take the form of a raster pattern of dots or a series of dots disposed laterally relative to the image and a series of dots disposed longitudinally relative to the image. The registration dots may be formed in the same way as the image, that is, by projection or by laser writing etc.

After the latent image and registration marks are formed on sleeve 82, the sleeve 82 is moved past the toning substation 90 where the latent image is developed. Toning substation 90 may comprise a quantity of liquid toner 98 in a container 100 which is applied to the surface of sleeve 82 through a roller 102. The toned but unfixed image is then moved to the image transfer substation 92 where it is transferred onto the bottom surface of substrate 80. The transfer is accomplished nearly contactless by employing a highly effective field between sleeve 82 and substrate 80 by means of electrodes 104 and 106 which are connected to a suitable power supply 108. The substrate 80 carrying the toned image is then passed through image fixing substation 94, which may comprise an air flotation bar having hot air at which location the image is permanently fixed to the substrate. Any toner remaining on the sleeve 82 is removed from sleeve 82 at the toner cleaning substation 96. This substation may comprise a shoe filled with Isopar (not shown) or other suitable cleaning fluid depending on the toner employed. The cleaning fluid is applied ultrasonically to sleeve 82. Sleeve 82 is then ready for recharging, reimaging, etc., if this be desired.

Stations 74, 76 and 78 include the same substations and operate in the same way as station 72. The color of the toner is, of course, different. Furthermore, these stations also include electro-optical sensors 110, 112 and 114 which are coupled to servo systems 116, 118 and 120 respectively. The servo systems are connected to the drive systems for the rollers on which the sleeves are mounted. The drive systems (not shown) can be adjusted to change the speed of rotation of the rollers and can also be moved laterally to laterally shift the rollers (i.e., along their axis of rotation).

In use the sensors 110, 112 and 114 detect the registration marks appearing on the substrate next to the image deposited thereon at the first image printing station and then through the servomechanisms adjust the speed of rotation and axial position of the sleeves at their respective stations so that the images deposited

thereon from the second, third and fourth sleeves will be in exact registration with the image from the first sleeve.

After the substrate 80 has passed through stations 72 through 78 it may be passed through a finishing station 124 where a glazing compound is applied (such as by a roller) to make the finished print glossy.

From there the substrate 80 may move to slitters, cutters, folders, supply rolls, etc., none of which is shown but presumed to comprise structure using the oncoming substrate.

In Figure 3 there is shown a roll 196 of the transparent electrophotographic material from which the sleeve 20, such as used in Figure 1, is made. This material may be welded or otherwise securely joined together to form a belt which is indicated at 20 either before or after the image has been applied. The image may be projected onto the master belt 20 optically, this being done by charging followed by imaging, toning and fixing. It is preferred, however, that the image be applied in a digital fashion so that there is no need for a screen and no problem deriving from optical projection means.

A suitable multi-colored pattern is scanned and its colors separated and digitized into bits which may be stored in an electronic store. This is indicated at 198. The store is then used to operate a galvanometer-type scanning mechanism for producing deflections in a light beam from a low power laser, such as for example, a helium-neon laser 200. The laser projects its modulated beam by way of reflecting means 202 and 204 onto the surface of the electrophotographic material of the roll 196 at 206 as this material is being unrolled. By suitable drives the reflecting means 202 and 204 are capable of correcting and compensating for the conversion from the continuous flow of bits to application to a surface as the beams swings back and forth. The material is first charged at 208, imaged at 206, toned at 210 and fixed at 212. The resulting image is now semipermanently fixed and the length of material may be cut from the roll 196 and formed into the sleeve 20 in the form of a belt by welding the ends together.

In Figure 4 there is illustrated another apparatus which can be used to make a sleeve 20 such as used in Figure 1. The sleeve 20 is in the form of a thin cylinder of metal or the like having a coating of the photoconductive material described mounted on a mandrel 214 which is driven. The same type of laser 216 as shown in Figure 3 at 200 fed from an electric store 217 directs a modulated beam of light 218 composed of digitized bits to a travelling mirror 220 mounted on a suitable driven guide rod 22 so that the digitized bits are properly laid down upon the surface of the sleeve 20 to produce the desired image representing a single color of a composite. A corona device 224 is arranged to charge the surface and toning device 226 is provided to tone it after the image has been laid down. At 228 one can see a representation of a toner fixing device which is on the opposite side of the view in Figure 4 to semipermanently affix the toned image to the sleeve 20.

After the sleeve 20 has been toned and the image fixed it is removed from the mandrel 114 and installed in an apparatus.

In Figure 5 there is illustrated a diagrammatic representation of an entire system 301 incorporating the apparatus of Figure 2 for making color prints from color transparencies.

A color transparency from which a color print is to be made is placed on a flatbed scanner 401 where the imagery is rapidly scanned (approximately 15 seconds), and dissolved into its information components, such as color type, density, hue and location. This information is fed through a minicomputer 403 into either a permanent memory 405 or into a temporary memory 407.

The computer provides via software instructions for the balancing of colors by adjusting dot size, location, and—if required—exposure energy, thus taking into account the characteristics of the printing toner. This ability of adjusting color balances also permits operator access, and therefore created deliberate adjustability of colors through control feedback from a computer terminal 409.

The computer terminal 409 allows the selection of scale, i.e., the enlargement factor, cropping of the image, color intensity control and—via a keyboard—alphanumeric tilting.

Upon command, information from the computer 403 is unloaded into an imaging module 411, which feature a multiple laser system for the generation of all four-color separations simultaneously onto four sleeves 413, 415, 417 and 419. The sleeves are charged electrostatically, imaged with said lasers and then toned so they can transfer the moist toned image onto a sheet of plain paper 421. The transfer is accomplished nearly contactless by employing electrical field between sleeves and paper carrier.

After the image is fully transferred, the paper is glazed to transparentize the toner and bond the image under a high gloss finish onto the paper.

Various modifications of the invention are capable of being achieved without departing from the spirit or scope of the invention as defined in the appended claims.

What it is desired to secure by Letters Patent of the United States is:

Claims

1. Apparatus for printing a composite pattern at least once upon a moving substrate, said pattern being made up of registered impressions of different images having different colors, said apparatus comprising:

A. a plurality of image printing stations, each being substantially similar in construction and adapted to produce a different color impression upon a substrate;

B. means for moving an elongate substrate through the apparatus from station to station,

C. each station comprising

i. a rotation sleeve, said sleeve having an image thereon in the form of a component of a composite image,

a. said sleeve being an electrophotographic member including an outer coating of photoconductive material,

b. said image being a tone image which has been formed electrostatically on said outer coating,

ii. means for transferring the toned image to a surface of the substrate while the substrate is moving through said station,

iii. means for fixing the image to said substrate surface before said substrate moves to the next following station to achieve an imprinted impression of a certain color,

iv. and means for removing any excess toner which is not transferred to said substrate surface if any had remained.

2. The apparatus as claimed in claim 1 in which the sleeve is arranged to rotate into a position juxtaposed relative to said substrate and at a peripheral speed which is the same as the linear speed of the substrate in moving through said station, and said station having means for effecting said transfer directly from the sleeve to the surface of the substrate as it passes through said station.

3. The apparatus as claimed in claim 2 in which the sleeve is in the form of a cylinder.

4. The apparatus as claimed in claim 2 in which the means for effecting transfer include electric field producing means for establishing an electric bias between the sleeve and the substrate effective to move the toner from sleeve to substrate.

5. The apparatus as claimed in claim 2 in which the means for removing excess toner comprise cleaning apparatus adjacent the sleeve after the position where the transfer is effected.

6. The apparatus as claimed in claim 2 in which the fixing means comprise a heater adjacent the surface of the substrate following the location in the station where the transfer is effected.

7. The apparatus as claimed in claim 3 in which the cylinder is formed of thin metal and the coating of photoconductive material is adhered directly to said metal.

8. The apparatus as claimed in claim 2 in which the charging of the fixed toner image is carried out in ambient light.

9. The apparatus as claimed in claim 4 in which the field producing means comprise a pair of electrodes connected to a power supply.

10. The apparatus as claimed in claim 1 in which the means for transferring the toned image to the substrate comprises a second rotating sleeve also being an electrophotographic member, charging means for charging a progressive part of the second sleeve in darkness, the first sleeve being spaced from the second sleeve and the first sleeve including means for optically projecting the toned image from the first sleeve to the second sleeve to expose the charged part for acquiring a latent image, means for toning the latent image on the second sleeve, the second sleeve being arranged to bring its toned image in juxtaposed relation to the moving substrate as it passes through the station and means for effecting the transfer from the second sleeve.

11. The apparatus as claimed in claim 10 in which one of the sleeves is a belt.

12. The apparatus as claimed in claim 10 in which both of the sleeves are belts.

13. The apparatus as claimed in claim 10 in which the means for effecting transfer include electric field producing means for establishing an electric bias between the second sleeve and the substrate effective to move the toner from the second sleeve to the substrate.

14. The apparatus as claimed in claim 13 in which the electric field producing means comprise a power supply and a pair of metal plates on opposite faces of the sleeve and substrate where they come together, the power supply being coupled to the plates.

15. The apparatus as claimed in claim 10 in which the toner is a mordant and the fixing means comprise a dye bath and rinse downstream of said second sleeve, the station having means for moving the substrate through said bath and rinse.

16. The apparatus as claimed in claim 10 in which means are provided to sense the density of said impression produced by said station and generate a signal for controlling the intensity of the projected image to maintain the said density at a predetermined value.

17. The apparatus as claimed in claim 10 in which the means for removing excess toner comprise a cleaning device adjacent the second sleeve at a location after separating from the substrate during its movement.

18. Method of printing composite color images on an elongated substrate wherein the colored images are produced repeatedly and spaced along the substrate and each is composed of a plurality of impressions of different color which comprises:

A. providing a plurality of printing stations, each station being arranged to produce an impression of a different color,

B. providing a sleeve of electrophotographic material at each station and rotating the sleeve continuously while simultaneously moving the substrate through the station, each sleeve carrying a respective toned image, corresponding to one color of the composite image,

C. transferring the respective toned image on each sleeve to the surface of said substrate as it passes said each station, and

D. fixing each toned image at its station after transfer on said substrate as the substrate moves, and before it enters the following station, and

E. the steps C for each station being timed to apply their toned images in registration.

19. The method as claimed in claim 18 in which the toned image is transferred directly onto the substrate.

20. The method of claim 18 and wherein the

toned image is transferred indirectly to the substrate by first optically projecting the toned image to a second sleeve.

21. The method as claimed in claim 18 in which the toned image is initially formed on said sleeve, then projected to a second sleeve of electrophotographic material, imaged and toned on the second sleeve and transferred directly from the second sleeve to said substrate.

22. The method as claimed in claim 18 in which said toner is pigmented.

23. The method as claimed in claim 18 in which said toner is a dye mordant type of toner and the fixing step comprises dyeing and rinsing whereby to render the fixed impression pigmented.

24. The method as claimed in claim 18 in which the density of the toned image on said substrate is measured after fixing and such measurement used to control the transfer.

25. The method as claimed in claim 18 in which the transfer to said substrate is aided if not effected electrically.

26. The method as claimed in claim 18 in which the image on the master sleeve is formed prior to use by digitizing a pattern and storing same, modulating a laser beam with the digitized information from said store and writing on said master sleeve, toning said sleeve and fixing the resulting developed image.

27. A method of making a color print of a color object, a color scene, a color pattern or the like on a substrate comprising:

A. providing a plurality of electrophotographic sleeves,

B. forming a toned image electrophotographically on each one of said sleeves, the toned image on each sleeve corresponding to a different color, image in the color print,

C. transferring the toned image from each sleeve onto the substrate successively and in exact registration.

28. The method of claim 27 and wherein the toned images are transferred to the substrate directly.

29. The method of claim 27 and wherein the toned images are transferred indirectly.

30. The method of claim 27 and wherein the toned images are formed on the sleeve by first charging the sleeve, then forming latent electrostatic images by laser writing and then toning the images so formed.

31. Electrophotographic color printing apparatus for making a multi-color print on an elongate substrate comprising:

A. a plurality of cylindrically shaped electrophotographic members positioned in side-by-side relationships and mounted for rotational movement about their longitudinal axis,

B. means for forming a toned image on each one of said electrophotographic members, the toned image on each electrophotographic member corresponding to a different color of said multi-color print,

C. means for moving said elongate substrate past each electrophotographic member in succession,

D. means for transferring the toned image from each electrophotographic member to the substrate in succession, and

E. means for regulating the speed of rotation and the axial position of the electrophotographic member so as to produce exact registration of the toned images as they are transferred on to the substrate.

32. A method of making a multi-color print of a picture, scene or the like comprising

A. converting said picture, scene or the like into digitized information,

B. using said digitized information forming a plurality of separate latent electrostatic images, each image corresponding to one color of said picture, scene, or the like,

C. toning each latent electrostatic image so formed with its proper color,

D. transferring each toned image to a substrate in sequence and in registration with one another so as to form the multi-color print, and

E. the transfer of each image being followed by the fixing of the image onto the substrate before the transfer of the next following image.

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